

1       **NON-WOVEN FABRIC**

2

3       This invention relates to a non-woven fabric and its  
4       uses, and relates more particularly but not exclusively  
5       to the use of a needlefelt for the covering of tennis  
6       balls, and to tennis balls so covered.

7

8       For the meaning of textile-related terms as used in  
9       this specification, attention is directed to the  
10      definitions in the reference book "Textile Terms And  
11      Definitions" (Eighth Edition) published in 1986 by The  
12      Textile Institute (of the United Kingdom). References  
13      in this specification to "tennis ball(s)" are to be  
14      taken as comprising references to analogous balls, i.e.  
15      to balls for games other than tennis but which are  
16      resilient hollow balls or otherwise structurally and  
17      functionally analogous to tennis balls, whether or not  
18      such analogous balls are interchangeable with tennis  
19      balls, and to felt-covered balls in general.

20

21      Traditionally, tennis balls have been covered with a  
22      felted textile material having a surface predominantly  
23      composed of wool fibres and based on a woven scrim or  
24      substrate. During the process of finishing the felted  
25      textile material, the scale structure of the wool

1       fibres is utilised to produce the characteristic felted  
2       surface appearance of the ball.

3

4       Nowadays woven felts for covering tennis balls are  
5       produced with a surface that is commonly composed of a  
6       mixture of wool and polyamide fibres. Usually these  
7       fibres are mixed at a ratio of about 60% wool & 40%  
8       nylon, but this ratio may vary in dependence on the  
9       wear characteristic required of the ball. It is also  
10      desirable that the back side of the felt (which is the  
11      side of the felt intended to be adhered to the core of  
12      the ball) be made of a material which provides a good  
13      adhesion when it is glued onto the hollow rubber sphere  
14      forming the core of the ball. Usually such backing is  
15      made of cotton.

16

17      Following the introduction of needlefelting machines,  
18      attempts have been made to produce and utilise  
19      needlefelts (felts composed of non-woven fabrics and  
20      produced by needlefelting machines) for covering tennis  
21      balls. Needlefelting techniques can be used to produce  
22      a non-woven fabric for covering tennis balls in  
23      accordance with the following method :- an appropriate  
24      blend of fibres, either dyed or undyed, is carded and  
25      cross-lapped to form a substantially horizontal fibre  
26      batt (a non-woven web). The fibres of the batt are  
27      provided in a generally planar configuration and are  
28      superimposed according to successive horizontal  
29      patterns. This batt is then passed through a known  
30      form of needlefelting machine. Such a needlefelting  
31      machine has at least one reciprocable panel (or  
32      "needleboard") comprising a cluster or array of barbed  
33      needles arranged mutually parallel, pointing in the  
34      same direction, and secured on a common substrate or  
35      mounting. The needlefelting machine may have two  
36      independently operable needleboards arranged on

1       mutually opposite sides of the fibre web and disposed  
2       in succession along the normally horizontal path  
3       followed by the batt as it passes through the machine  
4       during needlefelting operation. As the batt is passed  
5       horizontally through the needlefelting machine, the or  
6       each needleboard is vertically reciprocated to cause  
7       its cluster of barbed needles repeatedly to punch into  
8       and through the web, and then back out of the fabric  
9       web (on the same side as entry). The vertical passage  
10      of the barbed needles back and forth through the batt  
11      provokes a vertical entanglement of the fibres in the  
12      batt as the barbs of the needles carry some portion of  
13      the fibres along their pathways through the batt.

14  
15      Needlefelting machines have a higher productivity of  
16      fabric than looms producing woven fabric, and  
17      needlefelting machines will produce a felted fabric  
18      without the need to incorporate costly wool fibres and  
19      without the need to apply expensive finishing processes  
20      to the fabric. Consequently ball-covering needlefelts  
21      are cheaper than ball-covering woven fabrics. However,  
22      needlefelts lack the flexibility that is characteristic  
23      of woven fabrics, and consequently when balls are  
24      covered with shaped blanks of needlefelt, the seams of  
25      the covering are liable to be defective due to  
26      puckering of the blanks. Also, the so-covered balls  
27      tend to feel hard when hit, exhibit poor flight  
28      characteristics, and have poor wear resistance. These  
29      adverse properties arise from the smoother surface and  
30      greater consolidation of non-woven felts in comparison  
31      to woven felts.

32  
33      Attempts have been made to overcome the above-discussed  
34      defects of conventional needlefeltd ball coverings,  
35      for example by modifying needling density (needle  
36      penetrations per unit area of web), or by incorporating

1 a felt-backing scrim of greater flexibility; such  
2 attempts have not been successful. In a recent attempt  
3 to increase fibre entanglement in the finished felt, a  
4 percentage of wool fibre has been incorporated into the  
5 fibre blend prior to needlefelting, and the  
6 needlefelted fabric has been milled in a manner similar  
7 to the milling of woven felts. However, the non-woven  
8 fabrics that resulted from these procedures still  
9 failed to replicate the desirable characteristics of  
10 good-quality woven ball-covering felts.

11

12 A comparative study of the cross-sectional  
13 characteristics or microstructure of traditionally  
14 woven tennis ball felts and non-woven felts produced by  
15 needlefelting machines showed that fibres in woven felt  
16 are predominantly anchored in the base woven structure  
17 but are distributed in generally random directions  
18 throughout the surface pad of the felt, thus producing  
19 a high level of fibre intersections for a given density  
20 of felt. Also, the fibre density declines from the  
21 scrim (basecloth or backing) of the felt towards the  
22 opposite surface (normally the outer surface). The  
23 base structure retains a woven characteristic, and has  
24 a significantly greater fibre density than the outer  
25 surface. A typical woven ball-covering felt has a  
26 fibre density of 300 milligrams per millilitre at its  
27 base, diminishing to about 150 milligrams per  
28 millilitre towards the opposite (outer) surface. These  
29 characteristics, particularly the degree of fibre  
30 entanglement per unit density, are critical to the  
31 behaviour of the felt both during the ball-covering  
32 process and on the ball in play (i.e. in use).  
33 Conventional needlefelting techniques redistribute a  
34 proportion of the fibres laid predominantly  
35 horizontally during the cross-lapping process into a  
36 predominantly vertical configuration, the fibres

1       needled to verticality intersecting those not impacted  
2       by the needles at or close to right angles. Also, the  
3       fibre density (excluding any scrim material) can be  
4       seen to be nearly consistent throughout the thickness  
5       of the felt. From these observations it becomes  
6       apparent that the ratio of fibre intersections or  
7       degree of fibre entanglement is much lower in  
8       needlefelt than in woven felt for a given density of  
9       material. Thus, in order to achieve acceptable  
10      abrasion resistance and wear resistance characteristics  
11      in a ball that is covered in a needlefelt by means of  
12      giving the needlefelt a level of fibre entanglement  
13      that is comparable to that in a woven ball-covering  
14      felt, it is necessary to apply a high needling density  
15      (number of needle penetrations per unit of web area).  
16      High needling density renders the resultant needlefelt  
17      significantly less flexible than woven ball-covering  
18      felt, thus making the ball-covering process more  
19      difficult and more prone to defects. Balls covered  
20      with highly needled felt feel harder when hit than  
21      balls covered in woven felt, and generally fly faster  
22      due to the needlefelt surface being smoother and more  
23      consolidated than the surface of a woven felt. Such  
24      deficiencies may not be particularly significant for  
25      recreational use of tennis balls, but the defects in  
26      ball characteristics renders such balls unacceptable  
27      for use in professional tennis and in championship-  
28      level tennis matches.

29  
30      From the facts detailed above, it can be concluded that  
31      felting ball coverings produced using conventional  
32      needlefelting techniques cannot replicate the density  
33      and wear characteristics equivalent to woven ball-  
34      covering felts and simultaneously provide the  
35      performance characteristics required of good-quality  
36      tennis balls (e.g tennis balls of championship

1 standard).

2

3 It has now been discovered that a needlefelt produced  
4 by a needlefelting machine having a needleboard which  
5 is curved or otherwise shaped to ensure fibre  
6 entanglement in a range of angles (transverse to the  
7 plane of the felt web) exhibits surprisingly good  
8 characteristics of both wear and covering capabilities,  
9 and is particularly suitable for tennis ball coverings.

10

11 Such needlefelting machines are available from the  
12 Austrian Company Textiles Maschinenfabrik Dr E. Ferher  
13 AG and are known in the Trade as machines incorporating  
14 "Ferhrer H1 Technology" (see published British Patent  
15 Applications GB2306519-A, GB2310221-A, GB2312220-A,  
16 GB2315281-A, & GB2316957-A). However, these novel  
17 needle felting machines and techniques have never  
18 previously been proposed for production of a non-woven  
19 fabric having characteristics suitable to be used as a  
20 tennis ball covering.

21

22 According to a first aspect of the present invention  
23 there is provided a method of forming a felt covering  
24 for a ball, characterised by the steps of forming a  
25 needlefelt comprising an entanglement of fibres  
26 produced by needling a fibre batt in a range of angles  
27 including a plurality of angles which are non-  
28 perpendicular to the plane of the batt, and cutting or  
29 otherwise shaping the needlefelt to form a blank  
30 adapted at least partially to cover a ball.

31

32 The batt is preferably curved during needling, and  
33 where the batt is moved longitudinally as a step in the  
34 needling process, the batt is preferably curved in a  
35 longitudinal direction while being needled.

36

1 According to second aspect of the present invention  
2 there is provided a needlefelt for a ball covering,  
3 said needlefelt being characterised in that it  
4 comprises an entanglement of fibres formed by the  
5 needlefelting of a fibre batt passed through a  
6 needlefelting machine having at least one needleboard  
7 providing barbed needles to penetrate said web in a  
8 range of angles including a plurality of angles which  
9 are non-perpendicular with respect to the plane of the  
10 batt, and in that said needlefelt is cut or otherwise  
11 shaped to form a blank adapted at least partially to  
12 cover a ball.

13

14 During needling of the batt in the needlefelting  
15 machine the batt is preferably curved in the direction  
16 of its travel through the needlefelting machine, and  
17 the needleboard is preferably correspondingly curved.  
18 The needlefelting machine preferably comprises two  
19 needleboards at respective locations which are mutually  
20 displaced along the direction of travel of the batt  
21 through the needlefelting machine and which are  
22 preferably disposed to needle the batt from mutually  
23 opposite sides of the batt. Where the needlefelt  
24 incorporates a scrim, the first of said two  
25 needleboards is preferably disposed to needle the  
26 layered combination of batt and scrim from the side  
27 opposite to the scrim.

28

29 Prior to needled, the batt may be subjected to a  
30 preliminary consolidation and fibre entanglement in a  
31 pre-needling machine, the batt preferably being curved  
32 in its direction of travel through the pre-needling  
33 machine.

34

35 The ball is preferably a resilient hollow ball, and may  
36 be a tennis ball.

1 According to a third aspect of the present invention  
2 there is provided a felt-covered ball, characterised in  
3 that the ball-covering felt is a needlefelt comprising  
4 an entanglement of fibres formed by the needlefelting  
5 of a fibre batt passed through a needlefelting machine  
6 having at least one needleboard providing barbed  
7 needles to penetrate said web in a range of angles  
8 including a plurality of angles which are non-  
9 perpendicular with respect to the plane of the batt.

10

11 Said felt-covered ball preferably comprises a hollow  
12 resilient core to which the needlefelt covering is  
13 adhered, and said ball may be a tennis ball.

14

15 According to a fourth aspect of the present invention  
16 there is provided a felt-covered ball, characterised in  
17 that the ball is covered with needlefelt produced by  
18 the method according to the first aspect of the present  
19 invention.

20

21 According to fifth aspect of the present invention  
22 there is provided a felt-covered ball, characterised in  
23 that the ball is covered with needlefelt according to  
24 the second aspect of the present invention.

25

26 The ball according to the fourth or fifth aspects of  
27 the present invention may be a tennis ball.

28

29 Embodiments of the invention will now be described by  
30 way of example with reference to the accompanying  
31 drawings wherein :

32

33 Fig. 1 is a schematic representation of the needle  
34 paths followed by the needles in conventional  
35 needling in a conventional needlefelt;

36

1       Fig. 2 is a schematic representation of the needle  
2       paths following by the needle in the needlefelt  
3       applied to ball covering in accordance with the  
4       present invention; and

5

6       Fig. 3 is a schematic representation of a  
7       needlefelting machine and process for the  
8       production of a ball-covering needlefelt in  
9       accordance with the present invention.

10

11      Fig. 4 is a schematic representation of fibre  
12       entanglement in a conventional needlefelt.

13

14      Fig. 5 is a schematic representation of fibre  
15       entanglement in the needlefelt applied to ball  
16       covering in accordance with the present invention.

17

18      Referring first to Fig. 4, this is a schematic cross-  
19       section through a conventional needlefelt 9, the cross-  
20       section being taken in a vertical longitudinal plane.  
21      The needlefelt 9 is formed from a web or batt of non-  
22       woven fibres, the batt being of indefinite length from  
23       left to right as viewed in Fig. 4 (which depicts a  
24       short piece of the batt). The vertical lines shown in  
25       Fig. 1 (19) depict the needle paths followed by the  
26       needles during the conventional needlefelting process  
27       which provoke change of orientation of some of the  
28       fibres from initially horizontal alignments to vertical  
29       alignment (i.e. at right angles to the plane of the  
30       batt). It is to be particularly noted that the fibres  
31       in this conventional needlefelt 9 are entangled to a  
32       minimal extent.

33

34      Referring now to Fig. 2, this schematically depicts the  
35       needlepaths 28 of needles used to produce a needlefelt  
36       18 as shown in Fig. 4 with highly entangled fibres.

1 Such needlepaths are produced by the needlefelting  
2 machinery about to be described with reference to Fig.  
3. To produce the needlefelt 18 of Fig. 5, an  
4 appropriate blend of fibres, either dyed or undyed, is  
5 carded and cross-lapped to form a fibre batt 10 (Fig.  
6) as a starting material for the needlefelting  
7 processes to follow. The batt 10 weighs between 350  
8 grams per square metre and 850 grams per square metre  
9 depending on the weight required for the finished  
10 product. The fibres of the batt 10 could be composed of  
11 a mixture of wool and polyamide fibres, but other  
12 fibres could be incorporated or substituted as  
13 necessary or desirable.

14

15 The batt 10 is then passed through a pre-needling  
16 needlefelting machine 11 wherein the batt is curved  
17 while being needled such that the needles penetrate the  
18 batt in a range of angles, including a plurality of  
19 angles which are non-perpendicular to the surface of  
20 the batt. The machine 11 has a correspondingly curved  
21 needleboard 12 containing about 5000 needles disposed  
22 in a down-punch configuration (i.e. the needles are  
23 driven into the batt from above). The pre-needling  
24 machine 11 is advantageously of the type described in  
25 GB2315281-A, and as sold under the Trade Name "Fehrer  
26 H1 Technology" by the Fehrer Company of Austria.

27

28 The shape and size of the needles selected for use in  
29 the pre-needling machine 11 would depend on the results  
30 required. These needles are preferably three-inch, 40-  
31 gauge needles with regular barbs. Draft (reduction of  
32 linear density by drawing or longitudinal stretching),  
33 needle penetration depth and penetration density  
34 (number of needle penetrations per unit area of batt)  
35 are varied according to product requirements. For a  
36 tennis ball covering of good quality it is preferred to

1 use a draft of about 15% and to provide a penetration  
2 depth of about 10 millimetres at about 80 needle  
3 penetrations per square centimetre of batt.

4

5 The pre-needled batt of fibres 13 as delivered from the  
6 pre-needling machine 11, together with an appropriate  
7 scrim (backing fabric) 14, are passed through a finish  
8 needling machine 15 with the width and length of the  
9 batt 13 being generally horizontal. The scrim 14 is  
10 preferably a polyester or polyamide warp knit with a  
11 weight of about 75 grammes per square metre. The  
12 machine 15 has two needleboards 16 & 17, each  
13 needleboard of the needleboards 16 & 17 containing  
14 approximately 5000 needles, the first needleboard 16  
15 being disposed in up-punch configuration and the second  
16 needleboard 17 being disposed in down-punch  
17 configuration. ("Up-punch" refers to the needles being  
18 driven into the batt from below, and "down-punch"  
19 refers to the needles being driven into the batt from  
20 above). Each of the needleboards 16 & 17 is curved in  
21 a longitudinal plane, i.e. a plane which extends in the  
22 direction of batt travel through the needling machine  
23 and which is also vertical to the lateral extent of  
24 the generally horizontal batt 13 (e.g. as described in  
25 GB2306519-A & GB2312220-A), the batt 13 (and scrim 14)  
26 being correspondingly curved during needling by the  
27 respective needleboards 16 & 17. Such curvature  
28 results in the batt 13 and scrim 14 being needled in a  
29 range of angles, including a plurality of angles which  
30 are non-vertical to the surface of the batt, thereby to  
31 produce a needlefelt in which the fibres are highly  
32 entangled (as depicted in Fig. 2).

33

34 At the upstream or input end of the needling machine  
35 15, the scrim 14 is in-fed to lie along and above the  
36 fibre batt 13. Thus the first (up-punch) needleboard

1 16 of the finish needling machine 15 will needle fibres  
2 from the fibre batt 13 upwardly through the scrim 14  
3 while the second (down-punch) needleboard 17 will  
4 needle fibres back down through the scrim 14 into the  
5 fibre batt 13. By selectively altering the punch  
6 density and the depth of needle penetration by the  
7 second needleboard 17 it is possible to controllably  
8 alter the fibre density through the thickness of the  
9 finished needlefelt 18.

10  
11 The needles selected for use in the finish needling  
12 machine 15 would depend on the results required. These  
13 needles are preferably 3-inch, 40-gauge needles with  
14 regular barbs. Draft, needle penetration depth and  
15 penetration density can be varied according to product  
16 requirements; by suitably varying these parameters it  
17 is possible to alter the flexing characteristics,  
18 surface appearance and wear characteristics of the  
19 product. For tennis ball coverings of a good quality  
20 it has been found that a penetration of 14 millimetres  
21 at down-punch and a penetration of 10 millimetres at  
22 up-punch with a punch density of 80 penetrations per  
23 square centimetre without drafting (i.e. without  
24 reducing linear density by drawing or longitudinal  
25 stretching) can produce good results with regard to  
26 meeting the performance characteristics required for  
27 championship tennis. Reference to Fig. 2 will show the  
28 reason for this improvement in properties, namely the  
29 entanglement of fibres at various different angles due  
30 to the several different needle penetration angles  
31 arising from the imposition of longitudinal curvature  
32 on the batt as it is needled (see Fig. 6 of GB2310221-  
33 A, & Fig. 1 of GB2312220-A).

34  
35 The needlefelt tennis ball covering material so  
36 produced may optionally be subjected to further

1 processing. For example, a woollen milling process  
2 can, if required, be used to enhance the felt  
3 characteristics, particularly in respect of appearance  
4 and some aspects of wear. Additionally, the needlefelt  
5 may be dyed at this stage and dried. A shearing or  
6 cropping process may also be deemed appropriate.

7  
8 The needling process carried out on longitudinally  
9 curved batt produces fibre entanglement by moving  
10 fibres through the thickness of the felt at angles  
11 other than the conventional 90 degrees to the felt  
12 surface thus giving increased fibre to fibre contact at  
13 lower punching densities. This allows the manufacture  
14 of a needlefelt having high levels of fibre  
15 entanglement but without excessive consolidation. By  
16 using such needlefelting technology and controlling the  
17 depth of needle penetration it is possible to vary and  
18 control the density of the felt through its thickness.

19  
20 To make a tennis ball covered by the needlefelt  
21 obtained by the process described with reference to  
22 Fig. 3, suitably shaped blanks are cut from the  
23 needlefelt, and then glued on to a ball core  
24 constituted by a resilient hollow rubber sphere of  
25 appropriate dimensions. Such blanks may be the  
26 "figure-eight" blanks traditionally used in pairs for  
27 forming the covering of a tennis ball. The scrim 14  
28 provides a smooth backing surface enabling good  
29 adhesion between the needlefelt and the hollow rubber  
30 core of the ball.

31  
32 The preferred needling machinery for producing ball-  
33 covering felts is schematically depicted in Fig. 3, but  
34 modified arrangements may be utilised. For example,  
35 two separate needling machines (not shown) may be  
36 utilised in tandem (with suitable synchronisation of

1 batt movement). Alternatively, a needling machine with  
2 only a single needleboard may be utilised. The pre-  
3 needling machine may be integrated with the needling  
4 machine, or omitted from the needlefelting process.

5

6 While certain modifications and variations of the  
7 preferred embodiments have been described above, the  
8 invention is not restricted thereto, and other  
9 modifications and variations can be adopted without  
10 departing from the scope of the invention as defined in  
11 the appended claims.

12

13